PROPOSED QUANTITY-DISTANCE RULES FOR HAZARD DIVISION 1.2 AMMUNITION

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ABSTRACT

An extensive Hazard Division (HD) 1.2 open-air testing program has been recently completed. In addition, in-structure effects have been examined by both the United States and the United Kingdom. The results of these programs and a literature survey form the basis for proposed changes to both the U.S. rules as well as to UK/NATO advice. This paper will describe these proposed new rules and compare them with the currently existing criteria.

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PROPOSED QUANTITY-DISTANCE RULES FOR HAZARD DIVISION 1.2 AMMUNITION

INTRODUCTION

1. As long ago as 1989 NATO AC/258 through its Ad Hoc Technical Working Party identified the need for a fundamental revision of the Quantity-Distance (Q-D) rules associated with the storage of Hazard Division (HD) 1.2 ammunition.

2. The rules that were current then, and which are in the process of being updated now, were reputed to be based on data from trials with 60 mm mortar ammunition. The data were supposedly of US origin but neither the US DDESB nor the NATO nations generally have been able to identify any such work. There is undoubtedly 60 mm calibre ammunition in the inventories of many nations but, apart from the possibility of some classification work that might have been carried out in the early days of this ammunition being brought into service, there is no evidence of any practical trials work having been conducted with such natures of ammunition to determine the hazards from storage type quantities.

3. Indeed there is no evidence of any practical trials work which could be used to underpin the HD 1.2 Q-D rules which have been in existence since the early 1970's. So the question that is unanswered is "What exactly are the rules based on?"

4. Obviously there is no simple answer although the suspicion has grown that there never was any practical evidence on which to base a set of rules and that they were probably based on expert judgement at the time – the rationale for which, if indeed there ever was any, is hidden in the vaults of history.

5. Since the general NATO Q-D rules, currently enshrined in the Allied Ammunition Storage and Transport Publication, AASTP-1 (Ref 1), were originally developed the primary effort in validation has been aimed at the HD 1.1 Q-Ds. The practical trials effort in support of this validation has itself concentrated largely on intermagazine Q-Ds, particularly for earth covered structures. Little work has been done to either verify or indeed characterise the Inhabited Building, Public Traffic Route or Explosive Workshop (Intraline) distances. In addition, work was conducted in the late 60's to attempt to characterise the hazards associated with HD 1.3 type materials.

6. Even the definition of HD 1.2 suggests that it was not particularly well thought out and was only intended to cover the gap between the mass explosion effects from HD 1.1 and mass thermal effects from HD 1.3. It is only with practical accident experience from typical HD 1.2 ammunition that it becomes fairly obvious that the major effect is one of debris and that any blast or thermal effects are insignificant in comparison. There are, of course, some weapon systems around with very large individual HE contents that, in the event of an accidental initiation, would not propagate because of the stand-off to other similar weapons. Unfortunately by the very nature of the definition of HD 1.1 these fall naturally into HD 1.2.

7. For the purposes of this paper, and to keep life relatively simple, we will concern ourselves only with ammunition which contains less than 5 kg of HE in the warhead. For some natures there will be no HE content at all and the explosive content will comprise propelling charges, pyrotechnic compositions and the like.

8. We return then to the scene in 1989 when this subject was first discussed seriously. At the time the US and UK representatives drew up basic trials outlines which would allow the collection of data on which to base defensible Q-D rules.

9. It was decided to divide the problem into two parts :

a) To identify the hazards associated with accidental fires involving HD 1.2 ammunition in the open and

b) To consider what additional work needed to be conducted to allow the data from open stacks to be used for the more practical situation of storage in buildings.

10. At this time it was also identified that generic types of ammunition would be tested which could be considered to be representative of the overall HD 1.2 inventory and which would be available in sufficient quantities to make testing meaningful. The ammunition types eventually settled on were :

a) 105 mm HE fixed artillery rounds

b) 81 mm HE mortar bombs

c) 40 mm HE fixed rounds.

CURRENT RULES

11. The current NATO and UK Q-D prescriptions are defined in the AASTP-1 (Ref 1) for NATO and ESTC Leaflet 5 Part 2 (Ref 2) for the UK. Under this system, there is a broad division, based loosely on calibre, into:

a) Those items which give small fragments of moderate range (calibre < 60 mm): $IBD=53Q^{0.18}$ (IBD is inhabited building distance in meters, Q is Net Explosive Quantity (NEQ) in kilograms) with a minimum of 180 meters (591 ft) and a maximum of 410 meters (1345 feet).

b) Those items which give large fragments with considerable range (calibre > 60 mm): $IBD=68Q^{0.18}$ (IBD is inhabited building distance in meters, Q is Net Explosive Quantity (NEQ) in kilograms) with a minimum of 270 meters (886 feet) and a maximum of 560 meters (1837 feet).

12. US Q-D regulations are defined in the Department of Defense Ammunition and Explosives Safety Standards, DoD 6055.9–STD (Ref 3). Currently, for HD 1.2 items, safety distances are related to the maximum range of hazardous projections as determined by hazard classification tests performed for that specific ammunition item. For US items the IBD is given in hundreds of feet using the notation (xx) 1.2; for example, an item with an IBD of 1200 feet would be represented as (12) 1.2.

13. The NATO and UK criteria differ, in principle, from the current US criteria. The US criteria are round-specific and quantity-independent whereas the NATO/UK criteria are round-generic and quantity-dependent.

TESTING EFFORT

14. Both open-air and in-structure testing have been conducted as a part of this effort. Table 1 summarises the testing that was conducted in the open air. It should be noted that, with the exception of Test 11A which was intended as a confirmatory classification test, all testing was conducted using an external fire as the stimulus. The top part of table 1 lists those tests specifically conducted by US and UK as part of this effort, whilst the bottom part lists the

valuable contribution from Germany and Norway that identified the effects from the less hazardous natures of HD 1.2.

15. Table 2 summarises the work conducted inside structures using HD 1.2 105 mm HE ammunition. This work was inevitably somewhat uncoordinated largely due to the availability of existing structures which could be tested. Germany are still in the process of conducting tests using 40 mm ammunition, similar to that used in the open air testing, inside purpose built earth covered structures. Preliminary results from this work have been used to underpin the recommendations for these natures of ammunition although it is recognised that some fine tuning of the recommendations may be required once all the German data have been analysed.

16. Table 2 includes some work conducted by Japan on TNT loaded, 105 mm HE projectiles inside a tunnel to simulate underground storage.

TABLE 1 : HD 1.2 OPEN AIR TESTING

TEST IDENTIFIER	NUMBER OF ROUNDS	TEST DATE	TEST ITEM	TYPE OF BOX	TYPE OF TEST	COUNTRY
1	30	7-May-91	105 mm/TNT	Wood	External Fire	USA
2	30	24-Jun-91	105 mm/TNT	Wood	External Fire	USA
3	30	29-Jul-91	105 mm/TNT	Wood	External Fire	USA
4	240	29-Oct-91	105 mm/TNT	Wood	External Fire	USA
5	240	29-Apr-92	105 mm/TNT	Wood	External Fire	USA
6	864	28-Oct-92	105 mm/TNT	Wood	External Fire	USA
7	96	3-May-94	105 mm/COMP B*	Wood	External Fire	USA
8	180	15-Sep-94	105 mm/COMP B	Wood	External Fire	USA
8A	12	8-Sep-94	105 mm/COMP B	Metal	External Fire	USA
9	180	11-May-95	105 mm/COMP B	Metal	External Fire	USA
10	128	17-May-95	105 mm/COMP B	Wood	External Fire	USA
11A	15	20-Sep-95	81 mm/COMP B	Metal	Stack	USA
11B	15	20-Sep-95	81 mm/COMP B	Metal	External Fire	USA
12	720	26-Sep-95	81 mm/COMP B	Metal	External Fire	USA
	6912	Jul-80	40 mm	Metal	External Fire	USA
	80	1985-1986	40 mm	Metal	External Fire	NORWAY
	30	1985-1986	40 mm	Wood	External Fire	NORWAY
	240	Sep-95	40 mm	Plastic	External Fire	GERMANY
	224	Jan-96	40 mm	Plastic	External Fire	GERMANY
	480	Jan-97	40 mm	Metal	External Fire	GERMANY

*Tested without nose plugs

TABLE 2 : HD 1.2 IN-STRUCTURE TESTING

TEST IDENTIFIER	NUMBER OF ROUNDS	TEST DATE	TEST ITEM	TYPE OF TEST	COUNTRY
Japan	24	1-Dec-82	105 mm/TNT	Tunnel	Japan
SPANTECH-1	32	14-Nov-94	105 mm/COMP B	SPANTECH ECM	UK/AUS/USA
SPANTECH-2	32	16-Nov-94	105 mm/TNT	SPANTECH ECM	UK/AUS/USA
SPANTECH-3	32	19-Nov-94	105 mm/COMP B	SPANTECH ECM	UK/AUS/USA
SPANTECH-4	256	24-Nov-94	105 mm/COMP B	SPANTECH ECM	UK/AUS/USA
SPANTECH -5	4800	13-Sep-96	105 mm/COMP B***	SPANTECH ECM	UK/AUS/USA
MINIMAG	120	1-Jun-96	105 mm/COMP B	Miniature Magagine	USA
RED RIVER	5681	21-Aug-96	105 mm/COMP B***	ECM	USA
CAREWENDT-1	32	22-Jan-97	105 mm/TNT	Double-walled brick	UK
CAREWENDT-2	128	25-Jan-97	105 mm/TNT	Double-walled brick	UK
CAREWENDT-3	128	29-Jan-97	105 mm/TNT	Double-walled brick	UK

***Plastic Nose Plugs

SUMMARY OF TEST RESULTS

17. Each of the tests using 105 mm ammunition produced similar results with respect to spread of the fire, time to first reactions and duration of the event.

18. In each of the open air tests the fire developed rapidly with the entire stack engulfed in a few minutes. Typically the first explosive reactions occurred about 15 – 20 minutes after the initial ignition and the duration of the event varied from some 25 minutes for small stacks to some 50 minutes for the larger stacks.

19. The tests in structures exhibited almost identical reactions to the open air tests. The only notable exception was Spantech-5 which lasted several hours. This was largely due to the fact that the initial ignition involved only one small part of the stack inside the structure and the rest of the stack became involved through natural propagation of the fire, which is considered to be a more realistic accident scenario. The last of the stack did not become engulfed until some three or four hours into the test.

20. In all of the in-structure tests it would appear that the presence of a structure around the stack of ammunition being tested had little or no effect on the event itself. The stacks reacted in an almost identical fashion to the way they reacted in the open.

21. There was essentially no difference between the reaction of the rounds in relatively light weight brick structures or confining earth covered structures. The principal difference was in the actual quantities of fragments thrown out of the structure. In the case of the brick structures the walls very quickly disappeared because of the pressure generated from exploding rounds leaving the remainder of the stack exposed as it would have been if the building had not existed in the first place.

22. In the case of the earth covered structures the only escape route for fragments is through pre-defined openings in the structure, such as doors. The fragments thrown through such openings effectively behave as if they were from open air stacks but, of course, the hazarded area is limited to a few degrees either side of the opening. It therefore appears sensible to consider

the debris projected through any opening as being equivalent to that which would be projected (in the reduced sector) from the equivalent open stack.

23. Therefore for a strong building it can be assumed that there will be no debris projection in any direction other than the door. However it should be noted that the structure of the building is degraded markedly by the thermal effects from the fire, including of course the increased thermal attack from burning explosives. Although obviously projected items which impact on the walls have significant local effects it is the long term thermal degradation of the concrete structure which is most significant.

24. It should be noted that all of the tests used in the data analysis and referenced above were initiated by means of a fire which was generally representative of the wood fire used in the UN Series 6(c) test for hazard classification. Since the 105 mm HE round has been shown, as a result of extensive testing to be not capable of sustaining an HD 1.1 reaction it was considered that the most credible stimulus was that of fire.

25. In addition to the testing of 105 mm HE ammunition, which was generally considered to be the worst case, open air testing was also conducted on 81 mm mortar rounds and in fact some of these data drive certain parts of the new Q-D tables for these natures of HD 1.2 ammunition. However in general the 105 mm results are more conservative and therefore no tests were conducted inside structures using 81 mm ammunition.

26. Both open air and in-structure tests were conducted using 40 mm ammunition by Germany. This followed on from some earlier work conducted by Norway as a result of an accident involving transportation of 40 mm ammunition.

27. Also quoted in Table 2 is a test with 40 mm ammunition conducted in 1980 by the DDESB as part of their fragment hazard investigation program. Early tests in those investigations identified that the range of fragments thrown out of the tests was too great for the preliminary test site. This resulted in a final test being conducted involving some 36 pallets (6912 rounds) of ammunition. Rightly it was felt that the large number of rounds involved should have produced good, coherent data. However these data have recently been re-examined by the US and it has been concluded that the data set was probably flawed. The exact nature of the rounds cannot be determined and there is a question mark over whether the test range had previously been contaminated by other fragmentation tests. Because of these questions this data set has been given less credibility than the more recent testing conducted by Germany and Norway and has not been extensively used in the present analysis.

28. The 40 mm behaviour mirrors very much that of the larger calibre rounds. The main differences are in the times to first reaction which measure only a few minutes for 40 mm as compared to the average 20 minutes for the larger calibres and the much more restricted range of throw for the ejected fragments.

29. During August 1996 an incident occurred at the US Army's Red River Depot involving a fire in an earth-covered magazine filled with HD 1.2 and 1.3 items. The results of this incident were very similar to that from the more controlled test Spantech-5.

PROPOSED HD 1.2 GUIDELINES

30. US Specific Definitions: The Net Explosive Weight (NEW) of an item (used for transportation) is the sum of the weight of the HD 1.1 and 1.3 material contained in an item. The Net Explosive Weight for Quantity-Distance (NEWQD) for an item is equal to NEW (NEWQD = NEW) unless testing has been conducted. Based on testing, the NEWQD may include a

reduced contribution (less than or equal to 100%) from the HD 1.3 material as a result of the HD 1.1 material being functioned. The NEWQD should be determined by the Single Package Test (UN Test 6 (a) or its equivalent), not the Bonfire Test (UN Test 6 (c)). The NEWQD for a specific item may be obtained from the Joint Hazard Classification System (JHCS). The Maximum Credible Event (MCE) is the NEWQD for a single donor multiplied by one (1) plus one-half (1/2) times the number of acceptors required in the UN Test 6 (b) Stack Test (Note: An approved lesser weight may be used if it has been demonstrated by testing or analogy.). The MCE for a specific item may be obtained from the Joint Hazard Classification System (JHCS).

31. The effects produced by the functioning of HD 1.2 items vary with the size and weight of the item. HD 1.2 ammunition is separated into two sub-divisions in order to account for the differences in magnitude of these effects for purposes of setting Q-D criteria. The more hazardous items are referred to as HD 1.2.1 items and have an NEWQD greater than 1.60 pounds. The less hazardous items, referred to hereafter as HD 1.2.2, have an NEWQD less than or equal to 1.60 pounds. These two HD 1.2 sub-divisions are shown below with their definitions:

a) HD 1.2.1: NEWQD > 1.60 pounds

b) HD 1.2.2: NEWQD ≤ 1.60 pounds

32. UK/NATO Definitions : After much discussion within NATO AC/258 the following has generally been agreed

a) For the purpose of determining Q-Ds a distinction, depending on the size and range of fragments, is made between those items which give fragments with a considerable range (classified as HD 1.2.1) and those which give fragments with a moderate range (classified as HD 1.2.2). HD 1.2.1 items are primarily HE projectiles (with or without propelling charges) with an individual NEQ greater than 0.71kg. HD 1.2.2 items include HE projectiles (with or without propelling charges) with an individual NEQ less than or equal to 0.71 kg and other items not containing HE such as cartridges, rounds with inert projectiles, pyrotechnic items or rocket motors.

b) Fragments and Lobbed ammunition from Rounds with an individual NEQ greater than 0.71 kg.

This, the most hazardous part of Hazard Division 1.2 comprises those rounds and ammunition which contain a high explosive charge and may also contain a propelling or pyrotechnic charge. The total explosives content of these rounds, etc will be greater than 0.71 kg. It is impractical to specify Q-Ds which allow for the maximum possible flight ranges of propulsive items but the likely range of packaged items, if involved in an accident during storage, is typical of this part of Hazard Division 1.2. Munitions which explode during an accident will rarely detonate in their design mode. In a fire situation explosive fillings may melt and expand, breaching their casings and then explode via cook-off or burning to detonation reactions. These explosions may involve anything from 100% to a very small percentage of the fill dependent on the amount of the filling that has escaped through the breach. The fragmentation produced by such reactions is totally different to that generated in a design detonation. The case splits open producing large (for a 105 mm shell, for example 2-3 kg) but comparatively few fragments with velocities of 100-500 ms^{-1}. These are likely to be projected further than the smaller fragments from the full detonation of similar munitions in a HD 1.1 reaction. Quantities of unexploded munitions, sub-assemblies or sub-munitions also may be projected to considerable ranges and will, due to thermal or mechanical damage, be more hazardous than in their pristine state. Data on individual round characteristics obtained from tests and accidental explosions may be used to determine the validity of including a specific round in this category or to reduce it to the lesser category described in Paragraph c) below. These items are hereafter called rounds of HD 1.2.1.

c) Fragments and Lobbed Ammunition from Rounds with an individual NEQ less than or equal to 0.71 kg.

This less hazardous part of Hazard Division 1.2 comprises those rounds and ammunition which contain a high explosive charge and may also contain a propelling or pyrotechnic charge. The total explosives content of these rounds, etc will be equal to or less than 0.71 kg. It will also typically comprise ammunition which does not contain HE and will include pyrotechnic rounds and articles, inert projectile rounds. Tests show that many items of this type produce fragments and lobbed ammunition with a range significantly less than that of items in b) above but of course greater than that of ammunition and explosives of Hazard Division 1.4. These items are hereafter called rounds of HD 1.2.2.

d) Subdivisions for Storage

It is important not to exaggerate the significance of the value of 0.71 kg used in b) and c) above. It is based on a break point in the database supporting the Q-D relationships and tables and the NEQ of the rounds tested. If comprehensive data are available for a particular item, then the item may be placed in that category of HD 1.2 supported by the data and allocated the relevant Q-Ds.

e) The total explosives content of rounds or ammunition classified as HD 1.2 is used in the computation of the NEQ for Q-D purposes.

33. IBD Relationships. Curve fits have been made to the debris density versus explosive weight data. These fits are of the form:

a) $\text{IBD} = A + B^* [\ln(\text{weight})] + C^* [\ln(\text{weight})]^2$

When weight is in pounds, IBD is in feet and when weight is in kilograms, IBD is in meters.

34. The actual relationships that have been derived are given below:

US

35. **HD 1.2.1** $\text{IBD} = -735.186 + 237.559^* [\ln(\text{number of rounds x NEWQD})]$

$$- 4.274^* [\ln(\text{number of rounds x NEWQD})]^2$$

with a 200 foot minimum distance. When stored in structures that may contribute to the debris hazard, the IBD for items with an MCE greater than 100 pounds is determined by the larger of the two distances—the one given in the above equation or the one given by the following equation:

36. Minimum Fragment Distance = -1133.9 + 389 * ln(MCE)

with a minimum distance of 670 feet and a maximum distance of 1250 feet.

37. **HD 1.2.2** $\text{IBD} = 101.649 – 15.934^* [\ln(\text{number of rounds x NEWQD})]$

$$+ 5.173^* [\ln(\text{number of rounds x NEWQD})]^2$$

with a 100 foot minimum distance. For both HD 1.2.1 and 1.2.2 Public Traffic Route (PTR) distance is computed as 60% of IBD and Intraline Distance (ILD) is computed as 36% of IBD.

38. Within the US, a third category of HD 1.2 items has been defined. These are referred to as HD 1.2.3 or Unit Risk HD 1.2. To achieve this classification, ammunition must satisfy either of the following sets of criteria:

a) Ammunition that satisfy the criteria for HD 1.6 with the exception of containing a non-EIDS (Extremely Insensitive Detonating Substance) device, or

b) Ammunition that does not exhibit any sympathetic detonation response in the stack test (UN Tests 6(b) or 7(g)) or any reaction more severe than burning in the external fire test (UN Test 6(c) or 7(k)), bullet impact test (UN Test 7(j)), and the slow cook-off test (UN Test 7(h)).

39. The IBD for HD 1.2.3 is determined by using the HD 1.3 Q-D tables for the NEWQD of the item multiplied by the number of rounds with a minimum fragment distance based on the HD 1.1 hazardous fragment areal number density criteria applied to a single round of the HD 1.2.3 ammunition.

40. Quantity-Distance Matrix: For many combinations of PES-ES (Potential Explosion Site-Exposed Site), it has been determined that zero Q-D is appropriate. For those combinations where zero Q-D is called for, practical considerations will dictate the distances. The basic US Q-D matrix is shown at Annex A. The actual distances proposed for HD 1.2.1 and HD 1.2.2 are shown at Annexes B and C respectively.

UK/NATO

41. **HD 1.2.1** $D2 = -167.648 + 70.345^* [\ln(\text{number of rounds x NEQ})]$

$-1.303^* [\ln(\text{number of rounds x NEQ})]^2$

with a 60 meter minimum distance.

42. **HD 1.2.2** $D1 = 28.127 - 2.364^* [\ln(\text{number of rounds x NEQ})]$

$+ 1.577^* [\ln(\text{number of rounds x NEQ})]^2$

with a 30 meter minimum distance. For HD 1.2.1, Public Traffic Route Distance (D6) is computed as 67% of D2 and Workshop Distance (D4) as 36% of D2. For HD 1.2.2, Public Traffic Route Distance (D5) is computed as 67% of D1 and Workshop Distance (D3) as 36% of D1.

43. Quantity-Distance Matrix: For many combinations of PES-ES (Potential Explosion Site-Exposed Site), it has been determined that zero Q-D is appropriate. For those combinations where zero Q-D is called for, practical considerations will dictate the distances. The basic NATO Q-D matrix is shown at Annex D. The actual table of distances proposed for AASTP-1 is shown at Annex E.

COORDINATION

44. These proposed changes have been widely coordinated both within the US and UK as well as NATO. Within the US, this coordination has included the DOD Explosives Safety Testing Steering Group (DDESTSG), the Joint Hazard Classification authorities for the Services, and the DDESB Secretariat. In addition, it has been briefed to the DDESB Members and is scheduled for a vote in August 1998.

45. Within the UK, this coordination has been focussed within the Explosives Storage and Transport Committee (ESTC) and the recommendations are being produced as an amendment to ESTC Leaflet 5 Part 2 for endorsement in October 1998.

46. Within NATO, comments were requested from the members of AC/258 and a special session of the AC/258 Ad Hoc Technical Working Party (AHTWP) has been devoted to this topic. It is anticipated that final endorsement of the proposals will be made in November 1998.

COMPARISON OF EXISTING AND PROPOSED RULES

47. US : Annex F is a graphical comparison of existing and proposed Q-D rules for HD 1.2 generally. The four horizontal lines labeled (18) 1.2, (12) 1.2, (08) 1.2 and (04) 1.2 are not intended to represent any specific munition or weapon but are indicative of the current Q-Ds that would be used for storage of HD 1.2 explosives which had been assessed as having fragment hazards of 1800, 1200, 800 and 400 feet respectively.

48. As can be seen from Annex F the proposed rules for HD 1.2 offer significant Q-D reductions over the existing rules for the smaller stored quantities with some increase (varying from minor to significant) in Q-D for the larger storage quantities. Note that the Q-D criteria for (18) 1.2 items (and (12) 1.2 items and (08) 1.2 items reclassified as HD 1.2.2) are reduced across the range (1-500,000 lb). The proposed rules are obviously quantity related whereas, of course, the current rules are not.

49. NATO/UK : Annex G is a graphical representation of existing and proposed Q-D rules for HD 1.2. For HD 1.2.2 the changes are quite substantial and represent the more fundamental understanding of the actual hazards associated with this sub-division of HD 1.2. For HD 1.2.1 the picture is not quite so straight forward – although again substantial reductions have been proposed at the upper and lower ends of the NEQ range, a slight increase is indicated in the NEQ range 1000 to 10,000 kg. Again this is simply a realisation of the better understanding of the actual hazard associated with this sub-division of HD 1.2.

CONCLUDING REMARKS

50. When these proposed changes are implemented in the United States and in the UK/NATO, a major step will have been taken towards the harmonization of the respective explosives safety standards of these groups.

51. Some differences will remain, however. These will form the basis for additional work and discussions in this area. These differences are in two major areas

a) the definition and use of Unit Risk 1.2 items and

b) the use of MCE and structural debris contribution for HD 1.2.1.

REFERENCES

1. Manual of NATO Safety Principles for the Storage of Military Ammunition and Explosives – AASTP-1, Edition No. 1, dated August 1997

2. Manual of Standards for Storage and Transport of Military Explosives – ESTC Leaflet No. 5 Part 2, Quantity-Distances for Military Explosives in Above-Ground Sites 1996 (File D/ESTC/10/1/9

3. DoD Ammunition and Explosives Safety Standards – DoD 6055.9-STD, Under Secretary of Defense for Acquisition and Technology, August 1997

US QUANTITY-DISTANCE MATRIX FOR HD 1.2.1, 1.2.2 and 1.2.3

(note: all distances shown are in feet)

To EXPOSED SITE (ES)		From POTENTIAL EXPLOSION SITE (PES)					
		ECM			AGS (H)	AGS (H/R)	AGS (L)
		S	R	F			
ECM (7 bar) (IMD)	S	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	R	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	FU	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	FB	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
ECM (3 bar) (IMD)	S	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	R	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	FU	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	FB	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
ECM (Undefined) (IMD)	S	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	R	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	FU	0 (note 1)	0 (note 1)	200/300/100	200/300/100	200/300/100	200/300/100
	FB	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
AGS (H) (IMD)	U	0 (note 1)	0 (note 1)	200/300/100	200/300/100	200/300/100	200/300/100
	B	0 (note 1)	0 (note 1)	200/300/100	200/300/100	200/300/100	200/300/100
AGS (H/R) (IMD)	U	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
	B	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)	0 (note 1)
AGS (L) (IMD)	U	0 (note 1)	0 (note 1)	200/300/100	200/300/100	200/300/100	200/300/100
	B	0 (note 1)	0 (note 1)	200/300/100	200/300/100	200/300/100	200/300/100
ILD		Note 2	Note 2	Note 2	Note 2	Note 2	Note 2
PTR		200/300/100	200/300/100	Note 3	Note 3	Note 3	Note 3
IBD		200/300/100	200/300/100	Note 4	Note 4	Note 4	Note 4

LEGEND

S – Side; **R** – Rear; **F** – Front: **B** – Barricaded; **U** – Unbarricaded; **FU** – Front Unbarricaded; **FB** – Front Barricaded
ECM – Earth-Covered Magazine (7-bar, 3-bar, undefined refers to the strength of the headwall)
AGS – Aboveground Site; aboveground, non earth-covered magazine, structure or storage pad
AGS (H) – Buildings with wall thickness > 17.7 inches of reinforced concrete (27.6 inches brick); as an ES, door is barricaded if it faces a PES
AGS (H/R) – AGS (H) with roof thickness > 5.9 inches of reinforced concrete; as an ES, door is barricaded if it faces a PES
AGS (L) – Light structure, open stack, truck, trailer, or railcar
IMD – Intermagazine Distance; **ILD** – Intraline Distance;
IBD – Inhabited Building Distance; **PTR** – Public Traffic Route Distance

NOTES

(1) Practical considerations will dictate specific separation distances
(2) ILD = 36% of IBD with a minimum distance equal to the Intermagazine Distance
(3) PTR = 60% of IBD
(4) Use equations in paragraph 35 through 39

GENERAL COMMENTS

(a) Where three distances are given, the first refers to HD 1.2.1 items with an MCE < 100 pounds, the second to HD 1.2.1 items with an MCE > 100 pounds, and the third refers to HD 1.2.2 items
(b) All IM distances for HD 1.2.3 items at the ES are 0 (Note 1)

US TABLE OF DISTANCES FOR HD 1.2.1

(All distances in feet)

EXPLOSIVE WEIGHT [1] (lbs)	IBD [2,3] (ft)	PTR [4] (ft)	ILD [5] (ft)	EXPLOSIVE WEIGHT [1] (lbs)	IBD [2,3] (ft)	PTR [4] (ft)	ILD [5] (ft)
				7,000	1033	620	372
2	200	120	72	8,000	1055	633	380
5	200	120	72	9,000	1074	644	387
10	200	120	72	10,000	1091	654	393
20	200	120	72	15,000	1154	693	416
40	200	120	72	20,000	1199	719	432
60	200	120	72	25,000	1233	740	444
80	224	134	81	30,000	1260	756	454
100	268	161	97	40,000	1303	782	469
150	348	209	125	50,000	1335	801	481
200	404	242	145	60,000	1362	817	490
300	481	289	173	70,000	1384	830	498
400	535	321	193	80,000	1402	841	505
600	610	366	220	90,000	1419	851	511
800	662	397	238	100,000	1434	860	516
1,000	702	421	253	150,000	1489	894	536
1,500	774	464	279	200,000	1528	917	550
2,000	824	494	297	250,000	1558	935	561
2,500	862	517	310	300,000	1582	949	569
3,000	893	536	322	350,000	1601	961	577
3,500	919	551	331	400,000	1619	971	583
4,000	941	565	339	450,000	1633	980	588
5,000	978	587	352	500,000	1647	988	593
6,000	1008	605	363	>500,000	Note 3	Note 4	Note 5

NOTES

(1) Explosive Weight = Number of Items x NEWQD
(2) IBD = -735.186 + [237.559 x (ln(number of items x NEWQD))] – [4.274 x (ln(number of items x NEWQD))^2]
IBD in feet, NEWQD in pounds; ln is natural logarithm
(3) Use of equation given in Note (2) to determine IBD ranges for other weights is allowed
(4) PTR = 60% of IBD
(5) ILD = 36% of IBD

GENERAL COMMENTS

(a) When stored in structures which may contribute to the debris hazard, the IBD for items whose MCE is greater than 100 pounds is determined by using the larger of the following two distances: those given in this table for the appropriate Explosive Weight or those given by the equation in paragraph 36 for the appropriate MCE.

US TABLE OF DISTANCES FOR HD 1.2.2

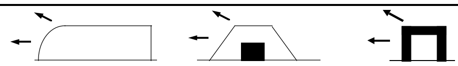
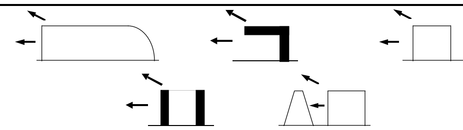
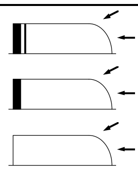
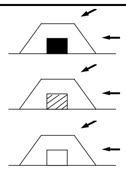
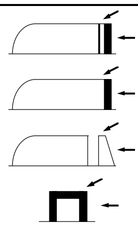
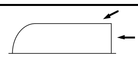
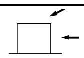
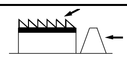
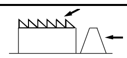
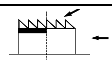
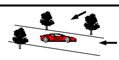
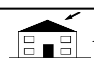
(All distances in Feet)

EXPLOSIVE WEIGHT [1] (lbs)	IBD [2,3] (ft)	PTR [4] (ft)	ILD [5] (ft)	EXPLOSIVE WEIGHT [1] (lbs)	IBD [2,3] (ft)	PTR [4] (ft)	ILD [5] (ft)
1	100	60	36	7,000	366	220	132
2	100	60	36	8,000	376	226	135
5	100	60	36	9,000	385	231	139
10	100	60	36	10,000	394	236	142
20	100	60	36	15,000	427	256	154
40	113	68	41	20,000	451	271	162
60	123	74	44	25,000	471	282	169
80	131	79	47	30,000	487	292	175
100	138	83	50	40,000	514	308	185
150	152	91	55	50,000	535	321	193
200	162	97	58	60,000	553	332	199
300	179	107	64	70,000	568	341	204
400	192	115	69	80,000	581	349	209
600	211	127	76	90,000	593	356	214
800	226	136	81	100,000	604	362	217
1,000	238	143	86	150,000	647	388	233
1,500	262	157	94	200,000	678	407	244
2,000	279	168	101	250,000	703	422	253
2,500	294	176	106	300,000	723	434	260
3,000	306	183	110	350,000	741	445	267
3,500	316	190	114	400,000	757	454	272
4,000	325	195	117	450,000	771	462	277
5,000	341	205	123	500,000	783	470	282
6,000	355	213	128	>500,000	Note 3	Note 4	Note 5

NOTES

(1) Explosive Weight = Number of items x NEWQD
(2) IBD = 101.649 – [15.934 x ln(number of items x NEWQD))] + [5.173 x ln(number of items x NEWQD))^2]
IBD in feet, NEWQD in pounds; ln is natural logarithm
(3) Use of equation given in Note (2) to determine IBD ranges for other weights is allowed
(4) PTR = 60% of IBD
(5) ILD = 36% of IBD

NATO QUANTITY-DISTANCE MATRIX FOR HD 1.2

Potential Explosion Site / Exposed Site			
	1	No QD_{ai}	No QD_{ai}
	2	No QD_{ai}	No QD_{ai}
	3	No QD_{ai}	No QD_{ai}
	4	No QD_{ai}	$D5_{bg}$ or $D6_{bh}$
	5	No QD_{ai}	$D5_{cg}$ or $D6_{ch}$
	6	No QD_{ai}	$D3_{eg}$ or $D4_{eh}$
	7	No QD_{ai}	$D3_{fg}$ or $D4_{fh}$
	8	No QD_{ai}	$D5_{fg}$ or $D6_{fh}$
	9	60m	$D5_{gk}$ or $D6_{hk}$ $D1_{gl}$ or $D2_{hl}$
	10	60m	$D1_{g}$ or $D2_{h}$

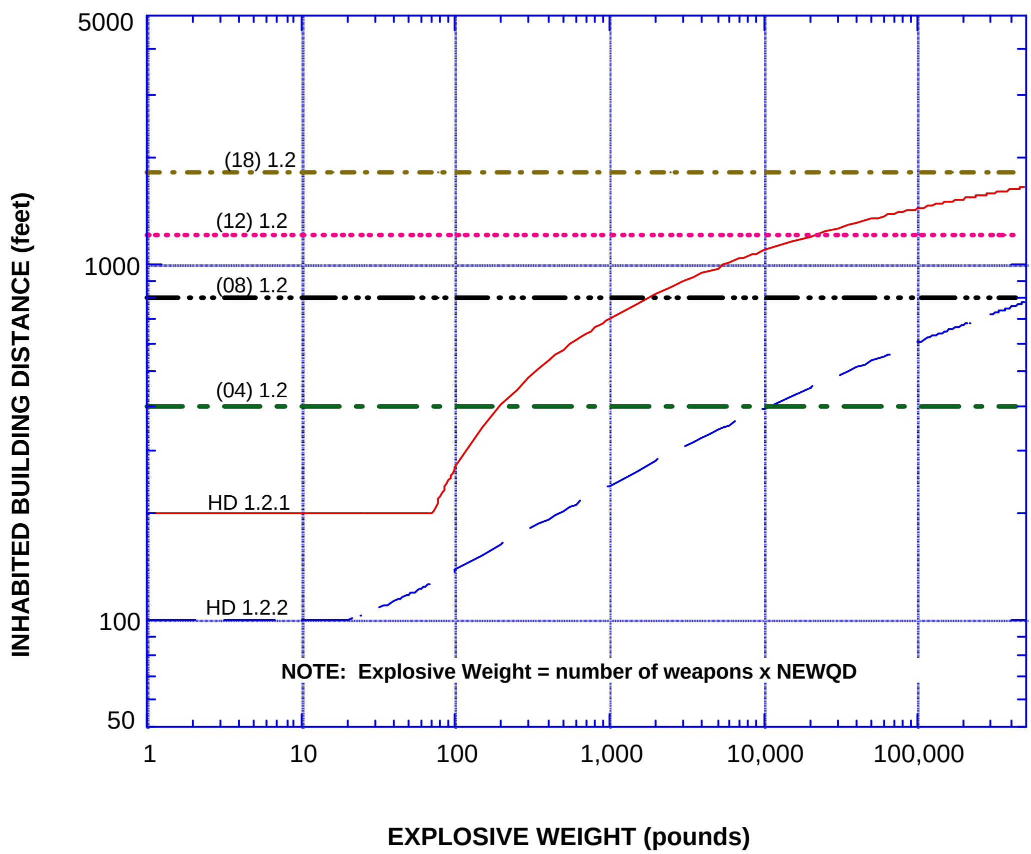
a. See virtually complete protection against propagation
b. See high degree of protection against propagation
c. See limited degree of protection against propagation
d. unallocated
e. see high degree of protection for personnel
f. see limited degree of protection for personnel
g. see PES contains only the less hazardous items classified HD 1.22
h. see PES contains the more hazardous items classified HD 1.21
i. see practical considerations will dictate specific separation distances
j. see unallocated
k. see low density traffic
l. see high density traffic

NATO TABLE OF DISTANCES FOR HD 1.2 (All distances in metres)

NEQ	Quantity-Distances					
	D1	D2	D3	D4	D5	D6
Kg	m	m	m	m	m	m
10	60	60	20	20	60	60
20	60	60	20	20	60	60
50	60	88	20	32	60	60
70	60	108	20	39	60	73
80	60	116	20	42	60	78
90	60	123	20	45	60	83
100	60	129	20	47	60	87
120	60	140	20	51	60	94
140	60	149	20	54	60	100
160	60	156	21	57	60	105
180	60	163	22	59	60	110
200	60	169	22	61	60	114
250	64	182	24	66	60	122
300	66	192	24	70	60	129
350	69	200	25	72	60	134
400	71	208	26	75	60	140
500	75	220	27	80	60	148
600	78	230	29	83	60	155
700	81	238	30	86	60	160
800	83	245	30	89	60	165
900	86	251	31	91	60	169
1000	88	257	32	93	60	173
1200	91	266	33	96	61	179
1400	94	274	34	99	63	184
1600	97	281	35	102	65	189
1800	100	287	36	104	67	193
2000	102	292	37	106	69	196
2500	107	303	39	110	72	204
3000	111	313	40	113	75	210
3500	114	320	42	116	77	215
4000	118	327	43	118	80	220
4500	120	332	44	120	81	223
5000	123	337	45	122	83	226
6000	127	346	46	125	86	232
7000	131	354	48	128	88	238
8000	135	360	49	130	91	242
9000	138	365	50	132	93	245
10000	141	370	51	134	95	248
12000	146	379	53	137	98	254
14000	150	386	54	139	101	259
16000	154	392	56	142	104	263
18000	157	397	57	143	106	266
20000	160	402	58	145	108	270
25000	166	412	60	149	112	277
30000	172	420	62	152	116	282
35000	177	426	64	154	119	286
40000	181	432	66	156	122	290
45000	184	437	67	158	124	293
50000	188	441	68	159	126	296
60000	194	449	70	162	130	301
70000	199	455	72	164	134	305
80000	203	461	74	166	137	309
90000	207	466	75	168	139	313
100000	210	470	76	170	141	315
120000	217	477	79	172	146	320
140000	222	483	80	174	149	324
160000	227	489	82	177	153	328
180000	231	493	84	178	155	331
200000	235	497	85	179	158	333
250000	243	506	88	183	163	340
500000	269	532	97	192	181	357

D1 = 28.127-2.364*LN(NEQ)+1.577*((LN(NEQ))^2)	D3 = 0.36*D1	D5 = 0.67*D1
D2 = -167.648+70.345*LN(NEQ)-1.303*((LN(NEQ))^2)	D4 = 0.36*D2	D6 = 0.67*D2

COMPARISON OF PREVIOUS/PROPOSED US REQUIREMENTS



Annex G

COMPARISON OF PREVIOUS/PROPOSED NATO REQUIREMENTS